Fact Sheet

EFFECT OF SOIL MOISTURE ON RADAR DETECTION OF SIMULANT MINES

BACKGROUND

A critical parameter affecting radar detection of buried land mines is the soil moisture content. Because of the high absorption coefficient of water at microwave frequencies, an increase in soil moisture content is typically associated with degraded radar performance. However, this is not necessarily true when detecting nonmetallic mines. The high dielectric contrast between nonmetallic mines and wet soil can offset the absorption loss so that radar sensor performance can improve as the soil moisture content increases.

VERIFICATION

Frequency modulated continuous wave (FMCW) radar operating at 2–6 GHz bandwidth was used to obtain images of nonmetallic simulant mines (SIMs)* buried in a sandbox. SIMs are filled with RTV silicone rubber, which has dielectric properties similar to TNT and Composition B, and therefore interact with radar sensors in a way representative of live mines. Figure 1 compares FMCW radar images of a 20-cm-diameter anti-tank SIM (buried 2.5 cm from surface) obtained at volumetric moisture contents of 5% and 10%. The figure illustrates a case study where the radar detection of SIM improves with increased soil moisture content.

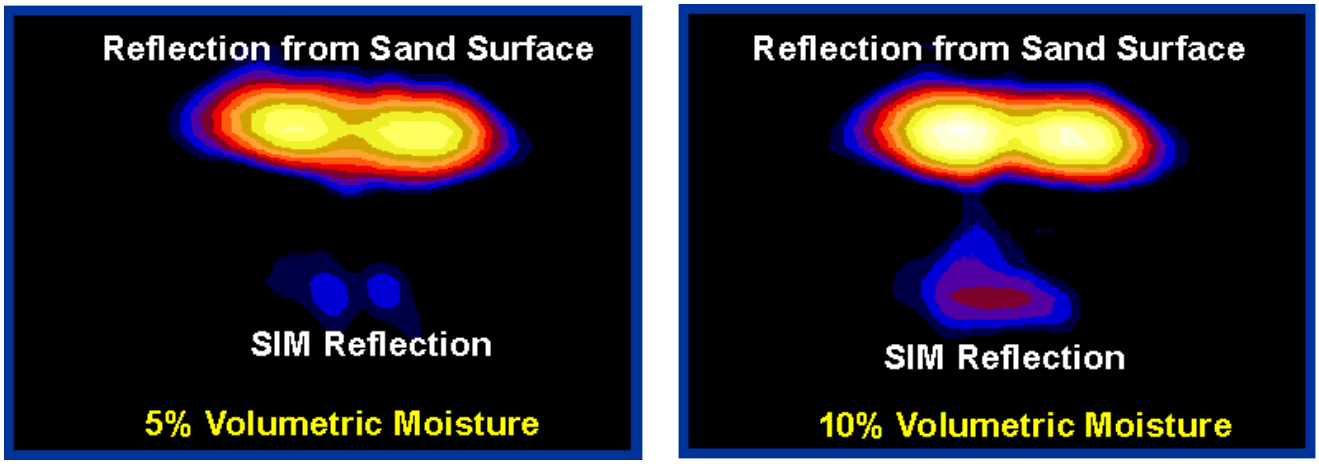

Figure 1. FMCW radar images of a 20-cm-diameter SIM buried in sand at 5% and 10% volumetric moisture

A simple layered-medium model was used to determine the relative radar signal levels expected from SIMs buried in sand as a function of burial depth and moisture content. These results were calculated using the complex dielectric constant of wet sandy loam measured at 1.4 GHz and 5 GHz by Hallikainen et al.† Figure 2 illustrates the relative signal levels expected from SIMs for a radar operating at center frequency of 3 GHz. These results are in agreement with the experimental observations that increased moisture content does not necessarily degrade the performance of radar sensors. For SIMs buried near the surface (<4 cm from surface) in a sandy environment, the optimal operating environment for radar sensors is around 10% volumetric moisture. For SIMs buried at depths greater than 4 cm, the increased dielectric contrast is not sufficient to offset the increased absorption loss due to water.

* Developed by the U.S. Army Project Manager—Mines, Countermine, and Demolitions; http://www.denix.osd.mil/denix/Public/News/UXOCOE/Sigdata/Mine/mine.html

† Hallikainen, M., F.T. Ulaby, M.C. Dobson, M. El-Rayes, and L.K. Wu (1985) IEEE Transactions on Geoscience and Remote Sensing, GE-23, 25.

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Cold Regions Research & Engineering Laboratory

CRREL, 72 Lyme Road, Hanover, NH 03755-1290

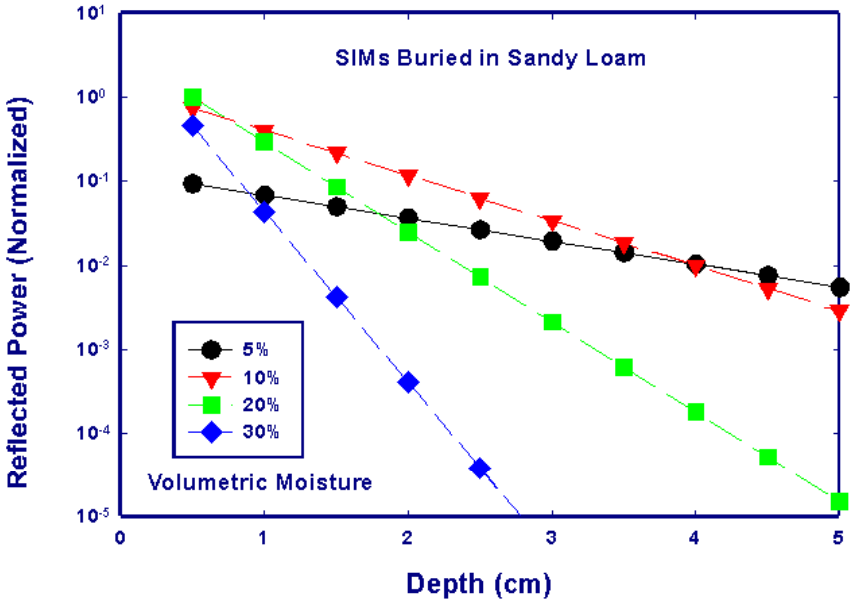

Figure 2. Relative radar signal level predicted for buried SIMs as a function of moisture content and burial depth (distance from top of SIM to ground surface).

SUMMARY

The optimal soil moisture content for radar detection of nonmetallic SIMs depends on the soil type, burial depth, and radar frequency. A case study illustrates that for radar operating at or near 3-GHz center frequency, the optimal moisture content for detecting SIMs that are buried less than 4 cm from the surface is approximately 10%. Additional case studies for different soil types and radar wavelengths are planned.

POINT OF CONTACT

Gary Koh
603-646-4282
Fax: 603-646-4397
E-mail: gkoh@crrel.usace.army.mil